(12) UK Patent Application (19) GB (11) 2 293 148 (13) A

(43) Date of A Publication 20.03.1996

(21) Application No 9518078.2

(22) Date of Filing 05.09.1995

(30) Priority Data
(31) 4432620 (32) 14.09.1994 (33) DE

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(51) INT CL[6]
B66F 9/075

(52) UK CL (Edition O)
B7H HXG H101 H103 H23X H303 H316
B7D DXA
U1S S1875

(56) Documents Cited
GB 2094727 A GB 1557714 A EP 0378202 A

(58) Field of Search
UK CL (Edition N) B7D DAWT DHF DHL DXA, B7H HXG, F2S SCA
INT CL[6] B60G 17/015 17/027, B66F 9/075
Online: WPI

(54) **Traction control of a drive wheel in an industrial truck**

(57) An industrial truck comprising a plurality of wheels including at least a propelling wheel 22 which is propelled by a motor 18 and which is provided with a braking means, which propelling wheel is pressed onto the floor by spring means 28, the biasing force of which is variable by a biasing means 30 in response to wheel slip detected by means 40, 42. The increase in biasing force is preferably impulsive.

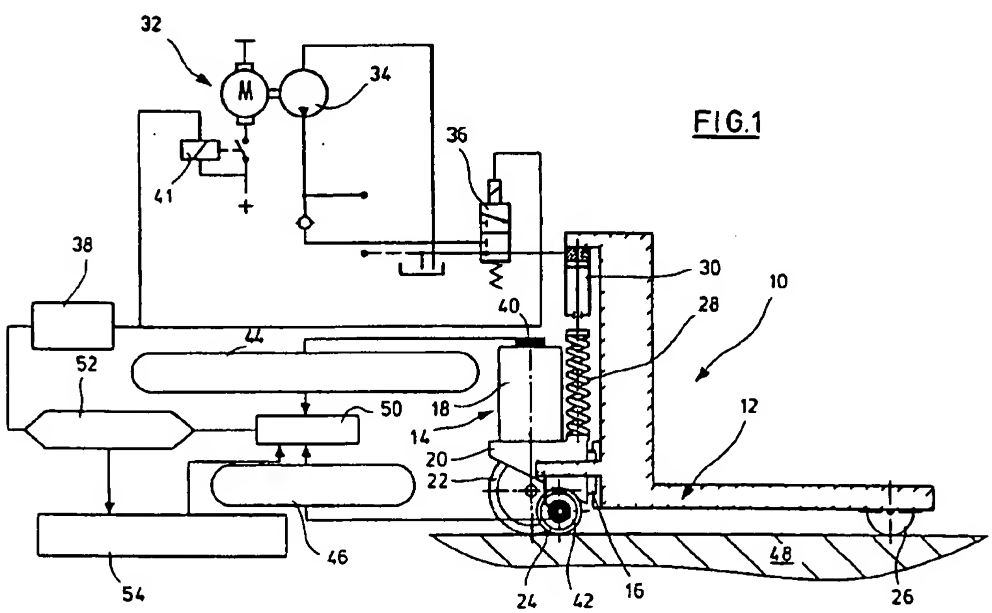

FIG.1

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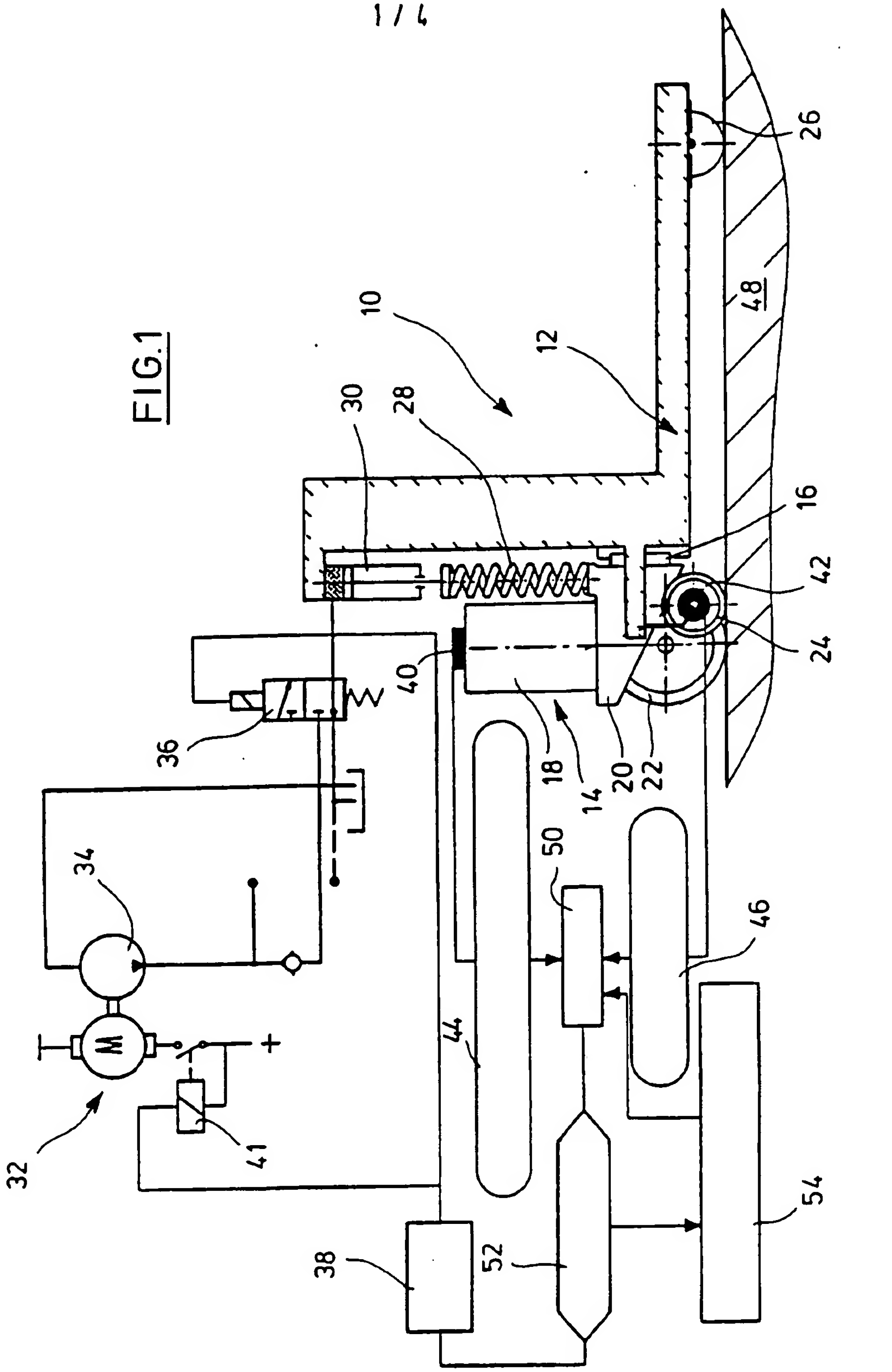

FIG.1

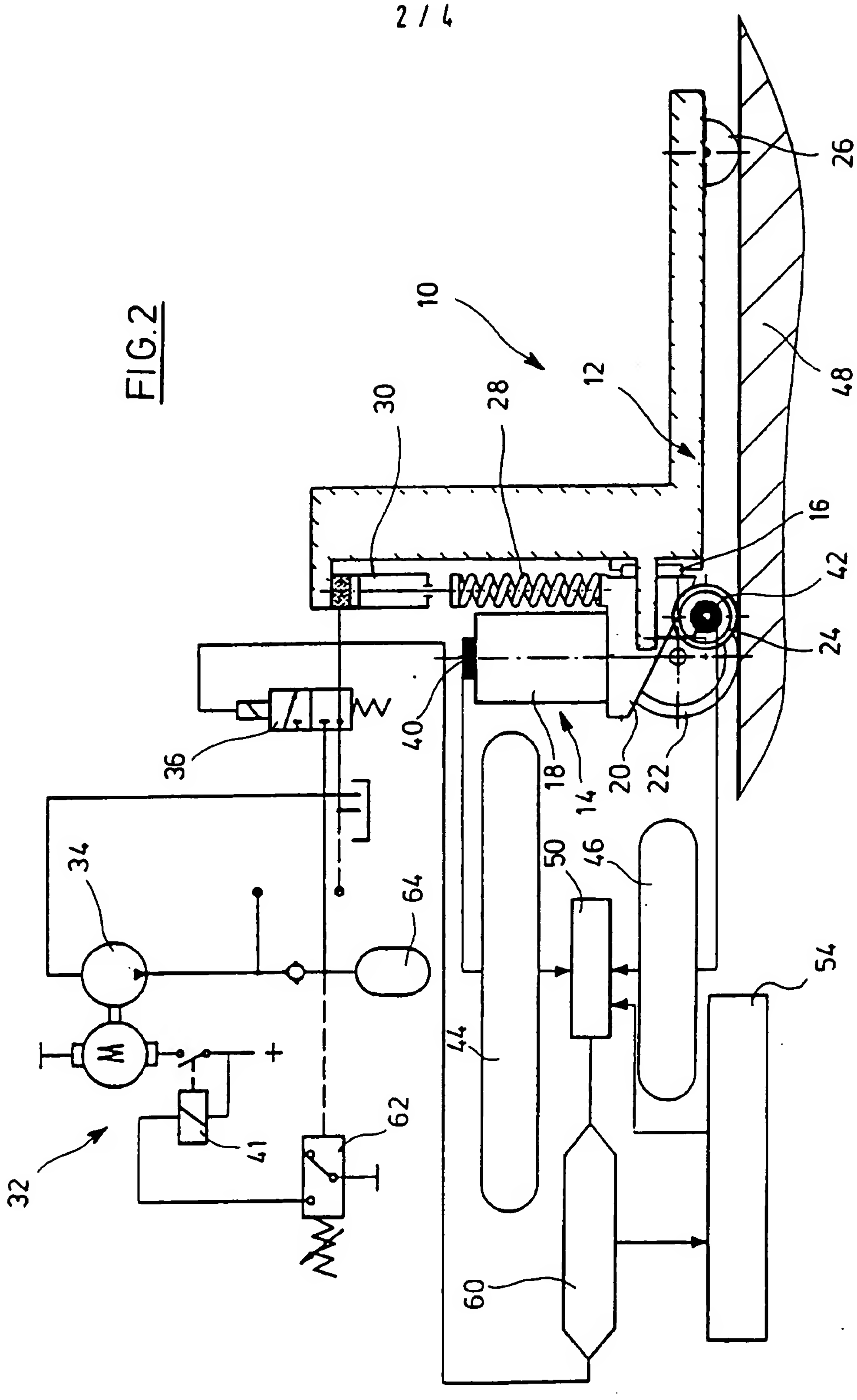
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FIG.2

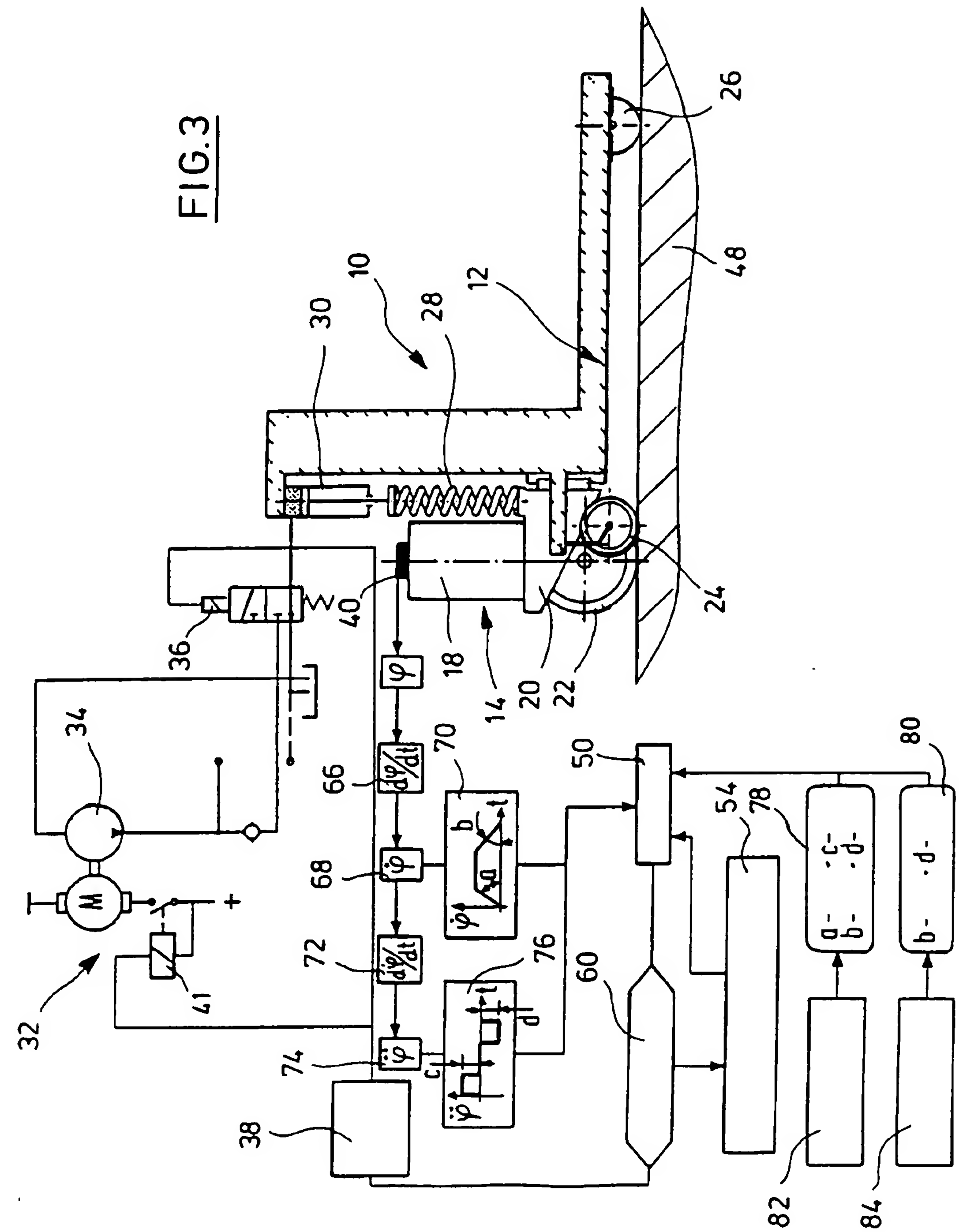
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FIG.3

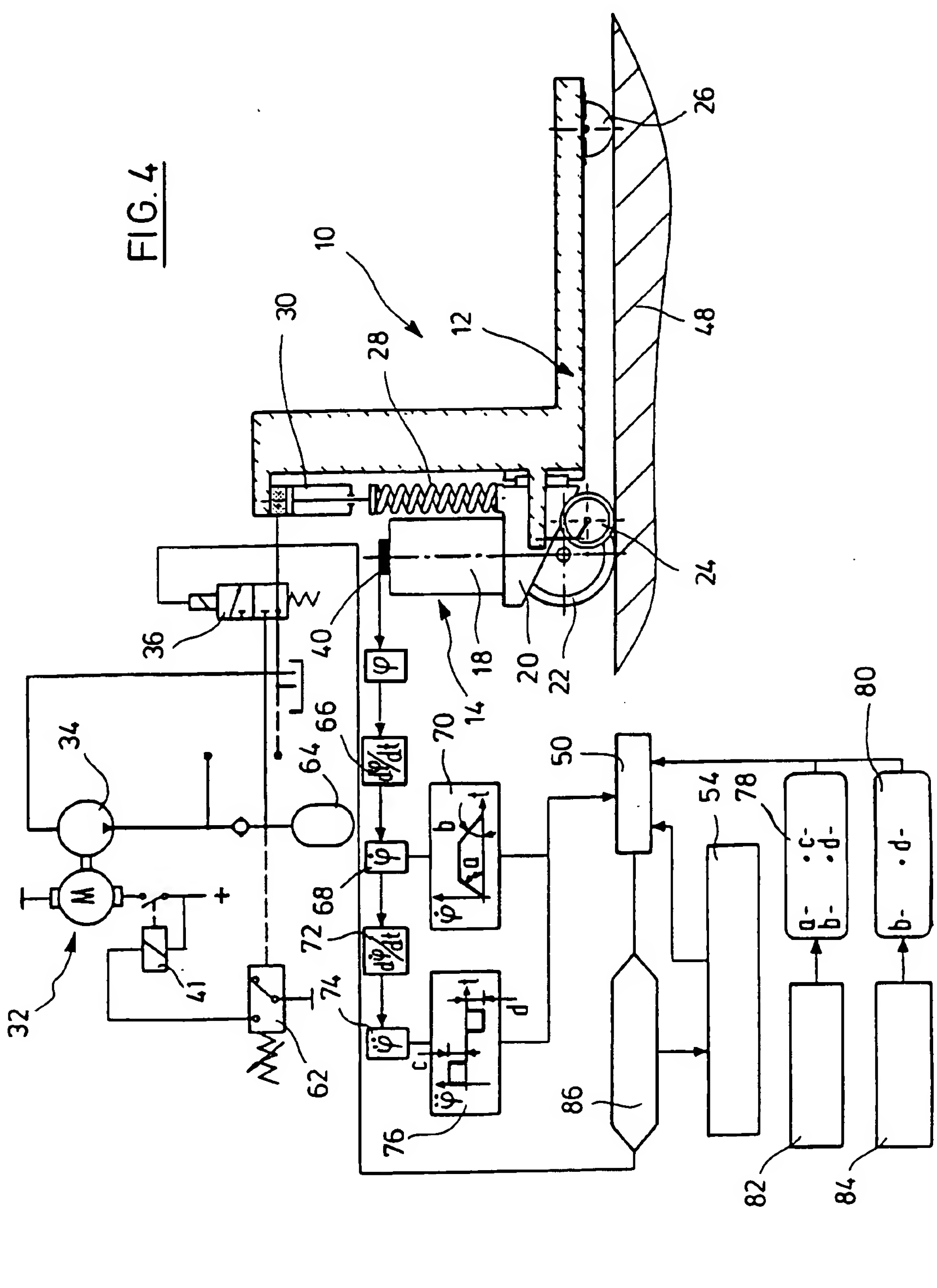
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FIG. 4

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Industrial Truck

The present invention refers to an industrial truck according to the preamble of claim 1.

Industrial trucks, in particular stop and go lift trucks for high and low lift ranges are required to meet four important requirements:

- The overall width of the vehicle shall be small, at least below the usual width of palettes (block stapling), wherein the vehicle wheels must be located within the vehicle contour.
- The vehicle shall be propelled with a speed as high as possible and shall be braked down according to specifications, and shall furthermore exhibit a high stability in maneuvering around curves.
- Loads as high as possible shall be lifted to magazine positions as high as possible.
- The steering forces shall be as small as possible.

The parameter substantially affecting all the items referred to is defined by the wheel/floor engaging force of the wheel which is propelled, braked and steered. Industrial trucks mostly employ an individual propelling wheel which is additionally provided with a braking means, although industrial trucks having a plurality of propelling wheels are known.

A high floor engaging pressure provides for good traction and an optimum braking exercising a minimum of slip. A high wheel/floor engaging pressure, however, makes steering more difficult and also increases the instability, in particular

while man uvering around curves or during a stillstand when th load is lift d to considerable heights.

It has been previously proposed to meet different conditions of operation by varying the biasing force of a spring producing the wheel/floor engaging force. DE 31 06 027 describes to reduce the biasing force when increasing the load or the lifting height. The load is sensed by measuring the pressure in the lift cylinder and the lifting distance is determined by measuring the position of the lift platform. EP 0 150 830 teaches to increase the biasing force in response to the following operational parameters:

- initiating a braking phase
- increasing slope of the floor
- increasing load torque of the propelling motor
- increasing slippery floor conditions
- arbitrarily by a manual actuation by the operator.

The document referred to further teaches to vary the biasing force in steps by a respective control of a hydraulic unit which may comprise a hydraulic accumulator.

It is known from EP 0 209 502 to continually vary the biasing force proportional to the load. To this end the pressure in the lift cylinder is sensed, or, respectively, the pressure in directly supplied to a biasing cylinder.

EP 0 329 504 specifies to provide for a load-responsive increase of the biasing force by sensing the load-responsive wheel pressure increase of the sideward supporting rollers located adjacent the propelling wheel.

It is common to all this prior art that they foresee critical conditions of operations which could result in a slip condition and that the wheel/floor engaging force is increased as a measure of precaution, properly assuming that a desired traction or a desired brake torque has to be

provided for. Howev r, whether the incr ase actually leads to the d sired result, remains open in that this is not investigated.

It is an object of the present invention to provide an industrial truck for which matching of the wheel floor engaging force to respective conditions of operation will be directly performed.

This object is solved by the features of claim 1.

The present invention is based on the very perception that the actual slip component occuring at a propelled, braked and/or steered wheel governs any variation of the wheel engaging force. In accordance with the prior art referred to the wheel engaging force is preventively varied in accordance with respective conditions of operation to counteract a spinning of the wheel propelled. Contrarily, according to the invention, the wheel pressure will be increased only then when a slip of the propelled wheel is determined. When this condition occurs the wheel is theoretically not anymore in a condition of adhesion friction, but rather in a condition of sliding friction. As the transfer from friction of adhesion to sliding friction is not linear, but stepwise, approximately the doubled wheel pressure is required for conditions of sliding friction in contrast to the pressure under conditions of adhesive friction provided the same transversal force between the propelled wheel (vulkullan bandage) and the floor shall be transferred. However, it has been shown that a far smaller increase of biasing force is required when the biasing force is impulsively increased to return a slipping wheel to the condition of floor adhesion.

It is possible to impulsively increase the biasing force in a single step when determining a slip condition. According to the invention, an alternative embodiment provides for producing a series of pulses to increase the biasing force

stepwise to the desired level.

When measuring a slip condition, it is further possible to provide a predetermined increase of the wheel engaging force which is sufficient in any case disregarding the magnitude of the slip. According to the invention it is further possible to determine the magnitude of the slip and to increase the biasing force in response thereto.

According to an alternative embodiment of the invention, the propelling or braking torque acting on the propelling wheel is turned off when a slip condition is determined, before activating the biasing means and subsequently turning on again. When the propelling wheel is merely spinning, it may be again transferred to the friction range of adhesion. When the wheel pressure is now increased, a higher peripheral force between the wheel periphery and the floor is available when propelling or braking is initiated as has been available at the time at which the floor adhesion has been lost.

The slip measurement according to the invention may be performed in two ways. The one way may be described as a direct method. The distance theoretically covered by the propelled and/or braked wheel as resulting from the product of wheel speed and wheel periphery is compared in certain times with the distance actually covered by the vehicle as measured by means of a just spinning wheel, i.e. a wheel which is neither driven nor braked. The result is evaluated with respect to a slip condition. In the so-called indirect method the motor shaft speed and/or the motor shaft acceleration is sensed in certain periods of time to be compared with fixedly stored desired values typical for the motor and the vehicle. According to an embodiment of the invention the sensor element may be an incremental angular encoder connected to a calculating means. When the calculating means determines a slip condition for the

propelling wheel, the spring bias force acting onto the propelled wheel is impulsively increased through a transducer. The transducer may be defined, for example, by a hydraulic cylinder, an electrical screw drive, a lift solenoid or the like.

Increasing the wheel pressure is constricted to certain limits. At a maximum the total vehicle load on the propelling axis is available which may be achieved in a plurality of steps or may be applied at once in a total amount to the respective propelling wheel.

Critical conditions of operation resulting in a slip condition while accelerating or decelerating only temporarily occur according to practice. According to an embodiment of the invention it is thus preferred to reset an increase of biasing force after a predetermined period of time and/or in response to a parameter of operation. When a slip condition again occurs after resetting the wheel pressure increase, the wheel pressure may be again increased as referred to above. Independent of conditions of time, the wheel pressure increase should be reset when the vehicle speed approximates zero or indeed comes to zero or when the load platform becomes located outside of the propelling range. Also in lifting a load to a certain height, resetting the wheel pressure increase will be useful to improve the stability of the truck. Also when the truck finds itself in an unstable condition and there is a danger of tilting over, the wheel pressure increase should be reset.

It should be understood that the propelled wheel has a minimum engaging pressure which is predetermined by the spring means for example. The wheel pressure increase referred to above in response to a slip measured thus refer to an increase of the biasing force beyond the minimum engaging pressure.

Th pr s nt invention will be describ d in more detail with ref renc to th drawings.

Fig. 1 shows a schematic wiring circuit of a first embodiment according to the invention;
Fig. 2 shows a slight modification of the embodiment of Fig. 1;
Fig. 3 shows a second embodiment according to the invention; and
Fig. 4 shows a slight modification of the embodiment of Fig. 3.

Referring to Fig. 1, a low board lifting truck 10 is shown comprising a frame 12 and a propelling unit 14 mounted thereon to be adjustable in height. The guiding means of the propelling unit 14 along the frame 12 is referred to at 16. The propelling unit 14 includes an electrical motor 18 which is mounted on a support 20. A propelling wheel 22 is carried by the support 20. The frame 12 further accommodates a pair of idle running wheels of which one is shown at 24 or, respectively, 26. Between the support 20 and an upper portion of the frame 12 there is provided a spring 28 producing a certain force acting on the propelling wheel 22. The spring engages the piston rod of a biasing cylinder 30 which is supported by the frame 12. By means of the biasing cylinder 30 the force of the propelling wheel acting on the floor can be varied. The lifting truck 10 further includes a motor/pump unit 32 providing pressurized fluid for performing a variety of hydraulic functions which are not shown. The pump 34 also delivers fluid to the biasing cylinder 30 through a three port/two position directional solenoid valve 36. A control unit 38 controls a relay 41 provided for the motor of the unit 32 and the solenoid of the valve 36.

An incremental angular encoder 40 is assigned to the shaft of the motor 18. A further angular encoder 42 is assigned to the wheel 24. A calculating means (not shown in detail)

comprising the stages 44 and 46 processes the desired and actual values of the distance of the truck 10 while moving about. The product of speed times the periphery of the wheel 24 is a measure for the actual distance covered. The product of motor speed times the wheel periphery divided by the gear ratio, if any, is a measure for the desired distance which should be completed in accordance with the biasing pressure of the wheel 22. When there is no slip of the propelling wheel 22 with respect to the floor 48, the actual and desired distance equal each other. However, when a slip occurs, this results in a difference which is determined in a comparitor 50. The comparitor 50 delivers a signal to a slip stage 52 which in turn controls the control unit 38. At the occurance of a slip, the control unit 38 can impulsively deliver signals to the relay 40 or, respectively, the valve 36. For example, a pulse of a predetermined length may be preset so as to impulsively increase the biasing of the spring 28 by supplying pressurized fluid to the biasing cylinder 30. The pulse length determines the increase of the biasing force and thus the force of the propelling wheel 22 for acting on the floor. It is also proper to deliver a series of individual pulses to the biasing cylinder 30 to increase the biasing force in individual steps. It is further possible to take the magnitude of the slip as a measure for increasing the biasing force, i.e. the biasing force becomes the higher the greater the slip is.

Since the slip-producing conditions mostly prevail temporarily only, the biasing force should be reduced again to a lower value. This may be obtained in a variety of manners. For example, the biasing force can be reduced as soon as a predetermined period of time has elapsed. Furthermore, a number of sensors may be provided for effecting a resetting of the biasing force when sensing certain conditions of operation, for example manouvering a curve, an unallowed tilting of the truck 10, a certain lift height of the load portion of the truck 10 and so on. This

is indicated by the stage 54 r c iving a signal from stage 52 when a slip condition has been determined. The stage 54 controls the comparator 50 for initiating a res t of the biasing force which has been increased.

The embodiment of Fig. 2 is distinct with respect to that shown in Fig. 1 in that the control means and the slip stage 52 are combined in a stage 60. The stage 60 supplies a control signal to the solenoid valve 36. There is a further distinction in that the relay 40 is controlled by a pressure switch 62 which is responsive to the pressure in a pressure accumulator 64 so that the pressure level in the accumulator 64 is maintained at a predetermined level. Accordingly the accumulator 64 supplies fluid to the biasing cylinder 30 when the biasing force shall be increased. Otherwise the operation of the embodiment shown in Fig. 2 is identical with that of Fig. 1.

As far as the embodiment shown in Fig. 3 comprises identical components as shown in Fig. 1, identical reference numerals are used.

The embodiment of Fig. 3 merely uses an incremental angular encoder 40. The rotational angle φ is differentiated in a differentiating stage 66, the stage 68 thus receiving the speed signal $\dot{\varphi}$. The variation of the speed is displayed in the stage 70. One realises a speed change including a slope a, a section of constant speed and a section where the speed decreases along a slope b. The slopes a and b correspond to actual values for a speed change while starting or, respectively, braking. The corresponding values for a-desired and b-desired are predetermined for a given motor power and a truck 10 of a particular type.

Therefore, the comparitor 50 compares the values a-actual and b-actual and the values a-desired and b-desired. When a difference results, this means a slip while accelerating or, respectively, decelerating. Accordingly, a slip stage 60 and

th control unit 38 act to control the biasing cylinder 30 in a manner already describ d.

Fig. 3 further shows that the speed is again differentiated after time to obtain the acceleration signal $\ddot{f}$. This is shown in stage 72 and 74. Stage 76 displays the acceleration values in a diagramm. They are characterized by the height c of the rectangular pulse indicating the acceleration and the height d for the deceleration prevailing in braking. The actual values for c and d may thus be also delivered to the comparitor 50 for comparing all actual values for the speed and acceleration or deceleration with the corresponding desired values. The values a-desired, b-desired, c-desired and d-desired are preset by a desired value transducer 82 of the truck 10. The values b-desired and d-desired are preset by a brake transducer 84. One realises that the embodiment shown in Fig. 3 is primarily distinct with respect to the embodiment of Fig. 1 in that a so-called indirect slip measurement takes place. Controlling the biasing cylinder 30, however, is the same in both embodiments.

Fig. 4 is substantially identical to Fig. 3. There is a difference in that the stage 38 and 60 of Fig. 3 is replaced by a common stage 86. Alike the embodiment of Fig. 2, there is a pressure accumulator 64 in which a predetermined pressure level is maintained by the motor pump unit 32. To this end pressure switch 62 is provided for controlling the motor of the unit 32. In all further details the operation of the embodiment of Fig. 4 corresponds to that of Fig. 3 so that it is not referred to it anymore.

CLAIMS

1. An industrial truck comprising a plurality of wheels including at least a propelling wheel which is propelled by a motor and which is provided with a braking means, which propelling wheel is pressed onto the floor by spring means, wherein the biasing force of the spring means is variable by a biasing means in response to a parameter of operation, characterized in that a slip determining means (40, 42) is assigned to the propelling wheel (22) and that the biasing means (30) increases the biasing force preferably impulsive when the means determine the occurence of a slip.

2. The industrial truck of claim 1, characterized in that the biasing force is impulsively increased in one or a plurality of steps.

3. The industrial truck of claim 2, characterized in that the magnitude of increasing the biasing force is responsive to the magnitude of the slip measured.

4. The industrial truck of one of claims 1 to 3, characterized in that the propelling or braking torque exerted on the propelling wheel (22) is turned off while determining a slip condition, before activating the biasing means (30), and is subsequently turned on again.

5. The industrial truck of one of claims 1 to 4, characterized in that an increase of the biasing force is completely or stepwise reset after a predetermined period of time has elapsed and/or in response to a parameter of operation.

6. The industrial truck of claim 5, characterized in that the vehicle speed zero and/or the position of the load platform and/or the height of the load platform and/or the tilt of the vehicle and/or the floor engagement of a

sideward supporting roller or the like is selected as a parameter of operation.

7. The industrial truck of one of claims 1 to 6, characterized in that the slip is directly measured and is determined by comparing the speed of the propelling motor 18 and the speed of a loosely rotating wheel (24) of the truck (10).

8. The industrial truck of one of claims 1 to 6, characterized in that the slip is indirectly measured by comparing the motor speed and/or the acceleration or deceleration and preset desired values (a-desired, b-desired, c-desired, d-desired) in predetermined periods of time.

9. The industrial truck of claim 7 or 8, characterized in that an incremental angular encoder (40, 42) including a calculating means is provided for speed sensing.

10. An industrial truck substantially as hereinbefore described with reference to the accompanying drawings.

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Patents Act 1977 **Examiner's report to th Comptr ller under Section 17** **(The Search report)**	Applicati n number GB 9518078.2
Relevant Technical Fields (i) UK Cl (Ed.N) B7D (DXA, DHF, DAWT, DHL), B7H (HXG), F2S (SCA) (ii) Int Cl (Ed.6) B66F 9/075, B60G 17/015, B60G 17/027	Search Examiner T S SUTHERLAND Date of completion of Search 30 OCTOBER 1995
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE: WPI	Documents considered relevant following a search in respect of Claims :- 1-9

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X: Document indicating lack of novelty or of inventive step.

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&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
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A	GB 1557714	(ASPRO)	
A	EP 0378202 A	(NISSAN)	

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